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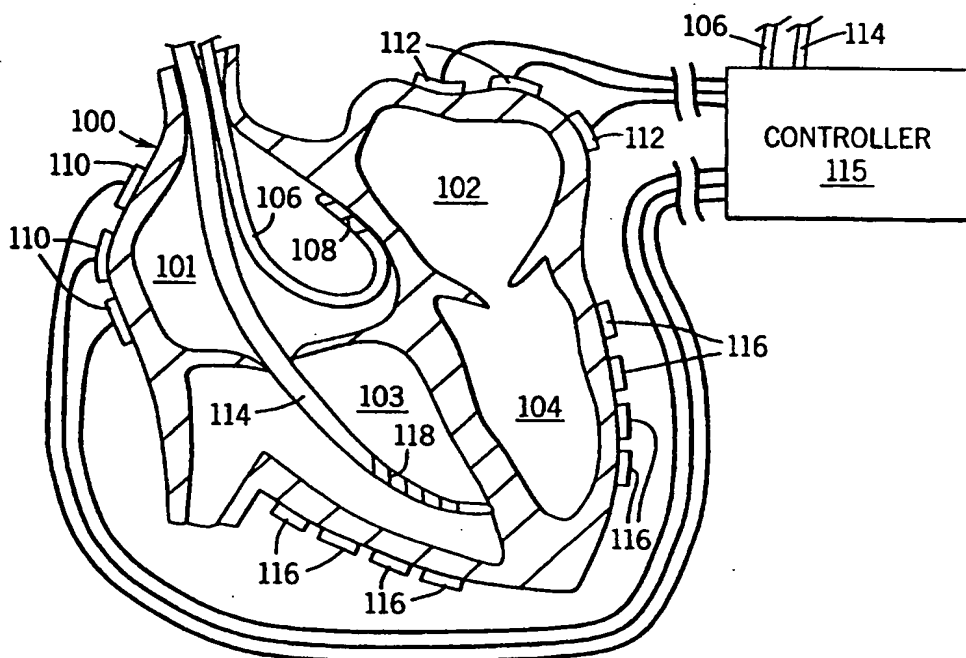
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(54) Title: ELECTROMAGNETIC HEART ASSIST TECHNIQUE



(57) Abstract

A heart can be artificially contracted to pump blood by separate electromagnets (112) to the exterior surface of the heart and implanting another electromagnet (108) inside a heart chamber. Electric currents are selectively applied to the electromagnets thereby producing magnetic fields which attract the electromagnets. That attraction generates forces which contract chambers of the heart and pump blood from those chambers. A technique for generating an electric current from a natural contraction of the heart is also described.

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ELECTROMAGNETIC HEART ASSIST TECHNIQUEBackground of the Invention

The present invention relates to artificial devices for assisting the pumping action of a heart.

Cardiac disorders often prevent the heart from being
5 able to contract properly and pump blood through the
arteries. One treatment involves surgically implanting an
artificial pacing device with electrodes attached to the
surface or inside of the heart. A controller of the implanted
pacing device periodically sends electrical pulses to the
10 electrodes which stimulate the heart muscle to contract and
pump blood from the heart chambers. This pacing action
controls the contraction of the heart thereby providing a
natural pumping action of the blood.

Individuals with more severe cardiac disease may not be
15 eligible for conventional pacing as the muscles of the heart
have deteriorated so significantly that external stimulation
will not produce sufficient pumping action. Treatment of
these individuals may involve cutting away a portion of a
ventricle of the heart and implanting an artificial pump in
20 the opening. The artificial pump supplements the heart's
pumping action. This radical solution often is the last
option available for the patient, as it permanently removes
part of the heart where the artificial pump is inserted.
Typically this treatment is used only to prolong a person's
25 life long enough to find a donor heart for transplantation.

Therefore, it is desirable to provide a technique for
artificially inducing contraction of a heart in individuals
with significant muscle deterioration, where the procedure is
less invasive and less radical than the surgical implantation
30 of an artificial pump.

Summary of the Invention

A general object of the present invention is to provide a technique and apparatus for artificially contracting chambers of the heart to pump blood in situations where conventional cardiac pacing is insufficient. This invention enhances the cardiac output of the heart.

Another object of the present invention is to utilize electromagnets to produce magnetic fields which cause contraction of the heart chambers.

10 A further object of the present invention is to utilize a plurality of electromagnets and control the application of electric current individually to each one so as to produce a controlled contraction which optimizes the pumping of blood.

These and other objectives are satisfied by a method for artificially contracting the heart in an animal to pump blood. A first magnet is attached on one side of a first chamber of the heart, wherein the first magnet produces a first magnetic field. A second magnet is attached on another side of the first chamber, wherein the second magnet produces a second magnetic field. In the preferred embodiment of the present method, both of these magnets are electromagnet coils which produce a magnetic field when an electric current is sent through the coils.

25 To contract the heart, the first magnet is selectively activated to produce the first magnetic field which interacts with the second magnetic field. That interaction generates a force which contract the first chamber of the heart.

The present method can be used to contract either one or both of the right and left ventricles of the heart. In that case, it is preferred to attach separate electromagnet coils to the exterior surface of the heart outside both ventricles. Another coil on a catheter is inserted into one of the

ventricles and secured to a wall of the heart. Pulses of electric current are applied to the different coils to produce magnetic fields which generate forces that attract the coils to each other and contract the right and left
5 ventricles.

Brief Description of the Drawings

FIGURE 1 is a cross-sectional view of a human heart to which the present technique is being applied;

FIGURE 2 is a detailed representation of a catheter
10 shown in Figure 1;

FIGURE 3 illustrates one of the external electromagnetic coils used in Figure 1;

FIGURE 4 illustrates an alternative embodiment of an external electromagnetic coil;

15 FIGURE 5 shows human heart with electromagnetic coils applied for a second embodiment of the present invention;

FIGURE 6 shows human heart with electromagnetic coils applied for a third embodiment of the present invention; and

FIGURE 7 is a cross-sectional view through a human heart
20 showing another application of the present heart stimulation technique.

Detailed Description of the Invention

With initial reference to Figure 1, a human heart 10 has a right atrium 11, a left atrium 12, a right ventricle 13 and
25 a left ventricle 14. Blood returning to the heart 10 from the body flows through the superior and inferior vena cava and passes into the right atrium 11 wherefrom it is pumped through the tricuspid valve 16 and into the right ventricle 13. Contraction of the right ventricle 13 causes the
30 tricuspid valve 16 to close in response to the generated

pressure and the blood to flow outward through the pulmonary arteries. After having passed through the lungs, oxygenated blood returns to the left atrium 12, where it is boosted into the left ventricle and thereafter pumped to the body through the aorta.

For hearts which are unable to pump an adequate amount of blood to the body, an artificial contraction assist device 18 is implanted into the patient. Using known procedures, a catheter 20 is introduced into any of several veins and advanced through the superior vena cava 21 into the right atrium 11. Further advancement causes the catheter 20 to pass through the tricuspid valve 16 and into the right ventricle 13. This procedure is similar to ones used in implanting catheters for conventional cardiac pacing devices. In those procedures, the catheter electrode tip ordinarily is wedged into the interior wall of the right ventricle pointing toward the apex 22.

The same general procedure may be followed to introduce the electromagnetic stimulation catheter 20 according to the present invention. That catheter 20 is preferably of a steerable type such as the one disclosed in U.S. Patent No. 5,674,271. The catheter 20 has electrical wires running there through to tip 24 where the wires connect to a coil 26 wound in a spiral lengthwise along the catheter as shown in Figure 2. Specifically, the coil 26 comprises an inner winding 25 and an outer winding 27 wound in the opposite direction coaxially around the inner winding. Because the inner and out windings 25 and 27 are wound in opposite directions, their individual electromagnetic fields add together. The steerable nature of the catheter 20 allows coil 26 to be placed against the septum between the two ventricles 13 and 14 as shown in Figure 1. The tip 24 may

include a corkscrew-like element for imbedding into the septum to secure the catheter in place. Alternatively, other techniques commonly utilized with pacing catheters may be employed to secure the catheter tip.

5 A plurality of electrical coils 28 are applied to the exterior surface of the heart outside the left ventricle 14. Another plurality of electrical coils 30 are applied to the exterior surface of the right ventricle 13. As shown in Figure 3, each electrical coil 28 and 30 preferably comprise
10 a flexible substrate 32 which is applied to the exterior surface of the heart 10 with surgical adhesive or stitches. An electrical spiral shaped coil 34 is on the substrate 32 and may be sandwiched between two layers of the substrate. The coil 34 can be formed by a wire that is wound in a spiral
15 on the substrate surface or can be formed by a thin layer of electrically conductive material that has been etched to form the spiral pattern. Electrical wires are connected to each end of the coil 34. Alternatively, the coils for one side of the heart could be formed on a single flexible substrate.

20 Other forms of electrical coils can be utilized with the present heart assistance technique. For example as depicted in Figure 4, the external coils 28 and 30 may be formed by an elongated spiral winding 35 carried by a strip-like flexible substrate 32. The flexible substrate 32 is applied in a
25 generally vertical orientation to the exterior surface of the heart 10 and held in place with surgical adhesive or stitches.

The wires in the catheter 20 and from the electrical coils 28 and 30 extend to a controller 36. This controller is similar to prior cardiac pacing devices which produce
30 electrical pulses applied to electrodes that stimulate a responsive contraction of the heart muscles. However, the present controller 36 applies pulses of electric current

6

through the various coils to generate magnetic fields that cause the coils to be attracted to each other in a controlled manner. Specifically, when a contraction of the ventricles 13 and 14 is desired, the controller 36 applies an electrical pulse of direct current, having a duration equal to that of the desired contraction, to the coil 26 of catheter 20. During that catheter pulse, pulses of direct current also are applied to the external electrical coils 28 and 30. The electric currents applied to the catheter coil 26 and the external electric coils 28 and 30 produce electromagnetic fields about those coils. Due to the direction of the direct current through each coil, the magnetic fields are polarized so that the external coils 28 and 30 are attracted toward the internal coil 26 of catheter 20. This magnetic attraction contracts the right and/or left ventricles 13 and 14 in much the same manner as though the heart muscles contracted the ventricles.

Typically the controller also receives an input signal from a plurality of sensors, collectively represented by sensor 39, which indicate when a natural contraction of the heart is occurring. The controller 36 responds to that signal by applying electrical pulses to the coils 26, 28 and 30. Usually the patient has some cardiac function which is a fraction (e.g. 50%) of the normal function. In this case the electrical pulses will be timed and applied at the end of the natural heart contraction to compress the ventricles the remaining amount to achieve full cardiac output. Thus the present technique increases the efficiency of a defective heart.

The controller can be programmed so that the external coils 28 and 30 for each ventricle 14 and 13 are pulsed separately or simultaneously. The magnitude of electrical

current applied to each coil 26, 28 and 30 can be regulated independently to produce the desired amount of heart contraction of each ventricle 13 and 14. For example, the controller 36 can vary the current magnitudes in response to sensing the pressure in the right ventricle by means of a pressure sensor 38 positioned on the catheter 20. The external coils 28 and 30 for a given ventricle may be pulsed in unison or sequentially pulsed by the controller 36 to squeeze the ventricle in a progressive manner from the apex 22 to the base or outflow area to force the blood from the ventricle through the aorta.

With reference to Figure 5, an alternative implementation of the present invention utilizes a plurality of external electromagnet coils 41, 42, 43, 44, 45, 46 and 47 with additional coils similarly positioned on the rear side of the heart 40. This embodiment eliminates the need for a catheter with a coil inside the heart. Each external electromagnet coil 41-47 comprises at least one loop 48 of an electrical conductor attached to a flexible substrate 49 which is applied to the exterior surface of the heart 40 with surgical adhesive or stitches.

To contract the heart 40, electric current is applied in opposite directions through adjacent coils 41-47. For example, the electric current may flow in the clockwise direction through the odd numbered coils 41, 43, 45 and 47 and flow counter-clockwise in the even numbered coils 42, 44 and 46. This produces oppositely poled electromagnetic fields in adjacent coils resulting in forces which cause attraction of the adjacent the coils. As the coils come toward each other the exterior wall of the heart 40 becomes pleated thereby contracting the ventricles. Similar electromagnet coils may be

applied to the upper portion of the heart to assist contraction of the atria.

Referring to Figure 6, a third embodiment of the present cardiac assistance technique applies a plurality of external
5 bands 51, 52 and 53 around the ventricular region of the heart 50. Each band 51-53 is formed by a series of segments coupled having ends coupled together by electromagnetic actuators. For example, the first band 51 has segments 54, 55 and 56 with other segments extending around the rear of the heart 50.
10 Each actuator 57, 58 and 59 of the first band 51 comprises a solenoid coil attached to one segment of the band with an armature connected to another segment. For example, actuator 58 has a solenoid coil 60 connected to band segment 55 and an armature 62 coupled to band segment 54. The bands 51-53 may
15 have various numbers of segments and corresponding numbers of actuators. At the very least a band has a single segment with one actuator coupling the ends of that segment together. In addition the number of bands applied to the heart may vary.

To produce contraction of the ventricles of the heart 50,
20 the controller applies electric current simultaneously to all of the actuators of a given band 51-53. For the first band 51 actuators 57, 58 and 59 will be energized simultaneously. This action creates electromagnetic fields which draw the armatures into the solenoid coils of the actuators 57-59,
25 thereby pulling the band segments 54-56 closer together. Thus the perimeter of the band 51 is reduced, contracting the heart 50. The other bands 52 and 53 may be contracted at the same time as the first band 51 or the bands may be energized sequentially starting with the band 53 closest to the apex 64.
30 This latter action produces a progressive contraction of the heart 50 toward the outflow area to force the blood from the ventricle through the aorta.

The present invention utilizes the electromagnetic attraction to assist the heart 10 in its natural pumping action. This technique, which does not require cutting the heart, is less invasive than previous artificial pump assisted techniques and replicates the natural pumping action of the heart. By utilizing a programmable controller 36, magnitude of the electromagnetic fields can be varied, thereby configuring the cardiac contraction force for each patient.

Moreover, the circulating blood does not leave the heart to be pumped as it does with current artificial pumps. Therefore, the potential for bleeding from the connecting in flow and out flow sites with current artificial pumps is eliminated. There is also less likelihood of blood clots forming because blood does not need to be in contact with artificial pump surfaces.

Figure 7 illustrates an alternative application of the present technique for patients with atria that do not contract fully. Such a condition also may interfere with the production of electrical pulses that are conducted by the heart to the atrioventricular node to produce regular contraction of the ventricles. The lack of full atrial contraction results in loss of the primer pump action (so-called "atrial kick") and the atrial contribution to ventricular function. Loss of atrial contraction can also result in blood clot formation in the atria and subsequent emboli, e.g. embolic stroke.

To enhance the pumping action of the atria, a catheter 106 with a spiral coil 108 near its tip is positioned within the right atrium 101 against the wall of the left atrium 102. A plurality of electrical coils 110 are attached to the exterior surface of the heart 100 outside the right atrium and a second plurality of electric coils 112 are similarly applied to the exterior of the left atrium. Each of these external

electric coils 110 and 112 have a structure similar to that described previously.

A conventional catheter 114, as used with cardiac pacing devices, is inserted through the right atrium 101 into the
5 right ventricle 103 and positioned adjacent to the septum between the right and left ventricles 103 and 104. In this application of the present invention, the atrioventricular (AV) node is disabled either with pharmaceuticals or by ablation techniques. As a result, electrical signals
10 produced for the atria do not travel to the ventricular region of the heart and conventional cardiac pacing must be employed to stimulate ventricular contractions.

A controller 115 is connected to the two catheters 106 and 114 and to the two plurality of external electrodes 110
15 and 112. To produce contraction of the atria 101 and 104 the pacer applies electrical pulses to the electrical coil 108 within catheter 106 and to each of the external electrical coils 110 and 112. The electrical currents applied to these coils create electromagnetic fields which result in
20 contraction of the right and/or left atria in a manner similar to that previously described with respect to the ventricles in the Figure 1 embodiment. By producing the electrical pulses at regular intervals, normal atrium contractions can be produced, and timed to augment ventricular function.

25 Because the AV node has been disabled the contractions of the atria do not produce the normal contractions of the ventricles 103 and 104. Instead, the controller 115 applies a conventional pacing pulse to the tip of the ventricular catheter 114 which stimulates the muscles of the heart to
30 contract the ventricles and pump blood therefrom. The controller 115 times the atrial and ventricular contractions to replicate those of a normal heart, i.e. electromagnetic

contraction of the atria can be specifically timed to precede the stimulation of the ventricles.

As the pumping force of the atria 101 and 102 is significantly less than that required for the ventricles 103 and 104. The use of an internal catheter 106 may not be required in all situations. As a consequence the atria pumping action may be achieved by merely the sets of external coils 110 and 112 and creating the properly poled magnetic fields from those coils to cause contraction of both atria.

Because the pumping of the ventricles 103 and 104 utilizes the normal muscle contraction of the heart in this latter embodiment, it is possible to produce some of the electrical power required by the controller 115 from the ventricular contractions. For this purpose a plurality of permanent magnets 116 can be attached to the exterior surface of the heart adjacent the right and left ventricles 103 and 104. In this enhancement, the ventricular catheter 114 has an additional electrical coil 118 adjacent its tip. As the normal ventricle contraction occurs the permanent magnets 116 move with respect to the catheter coil 118. The movement of the electric field produced by the permanent magnets with respect to the catheter coil 118 will generate an electrical current which can be utilized by the controller 115 to power the atrial stimulation.

The foregoing description is directed primarily to preferred embodiments of the invention. Although some attention was given to various alternatives within the scope of the invention, it is anticipated that skilled artisans will likely realize additional alternatives that are now apparent from the disclosure of those embodiments. Accordingly, the scope of the invention should be determined from the following claims and not limited by the above disclosure.

CLAIMS

I claim:

1. A method for artificially contracting a heart to pump blood, that method comprising steps of:

positioning a first magnet on one side of a first chamber of the heart, wherein the first magnet produces a first
5 magnetic field;

placing a second magnet on another side of the first chamber of the heart, wherein the second magnet produces a second magnetic field; and

selectively activating the first magnet to produce the
10 first magnetic field which interacts with the second magnetic field to contract the first chamber of the heart.

2. The method as recited in claim 1 wherein the first magnet is an electromagnet and the step of selectively activating the first magnet comprising applying electric current to the electromagnet to produce the first magnetic
5 field.

3. The method as recited in claim 2 wherein the second magnet is an electromagnet; and further comprising applying electric current to the second magnet to produce the second magnetic field.

4. The method as recited in claim 1 wherein the step of positioning a first magnet comprises inserting a catheter, to which the first magnet is attached, into a chamber of the heart and attaching the catheter to a wall of the heart.

5. The method as recited in claim 1 wherein the step of positioning a first magnet comprises inserting a catheter, to which the first magnet is attached, into a chamber of the heart.

6. The method as recited in claim 5 wherein the step of positioning a second magnet comprises attaching the second magnet to an external surface of the heart.

7. The method as recited in claim 5 further comprising positioning a third magnet on a side of a second chamber of the heart, wherein the third magnet produces a third magnetic field which interacts with the first magnetic field to contract the second chamber of the heart.

8. The method as recited in claim 1 further comprising positioning an electrode adjacent to the heart; and selectively applying electric current to the electrode which stimulates the heart to contract a chamber of the heart other than the first chamber.

9. The method as recited in claim 1 further comprising sensing a naturally occurring contraction of the heart; and wherein selectively activating the first magnet occurs in response to sensing a naturally occurring contraction of the heart.

10. The method as recited in claim 1 wherein the step of positioning a first magnet comprises placing a first band around the heart wherein the first band has ends coupled together by a first electromagnetic actuator in which application of electric current to the first electromagnetic actuator causes a reduction in a perimeter of the first band and contraction of the heart.

11. The method as recited in claim 10 wherein the step of positioning a second magnet comprises placing a second band around the heart wherein the second band has ends coupled together by a second electromagnetic actuator in which
5 application of electric current to the second electromagnetic actuator causes a reduction in a perimeter of the second band and contraction of the heart.

12. The method as recited in claim 1 wherein the steps of positioning a first magnet and positioning a second magnet comprise placing a band around the heart wherein the band includes a plurality of segments, the first magnet comprises a
5 first electromagnetic actuator which couples two of the plurality of segments and the second magnet comprises a second electromagnetic actuator which couples two of the plurality of segments; and wherein application of electric current to the first and second electromagnetic actuators causes a reduction in a perimeter of the band and contraction of the heart.

13. A method for artificially contracting a heart to pump blood, wherein the heart has at least first and second chambers, that method comprising steps of:

positioning a first electromagnet adjacent to the heart
5 outside the first chamber to produce a first magnetic field;
positioning a second electromagnet adjacent to the heart outside the second chamber to produce a second magnetic field;
implanting a third electromagnet inside one of the first and second chambers to produce a third magnetic field; and
10 selectively applying electric currents to the first, second and third electromagnets to produce the first, second and third magnetic fields which interact to contract the first and second chambers of the heart.

14. The method as recited in claim 13 further comprising varying the electric currents to control magnitudes of the first, second and third magnetic fields and thereby control contraction of the first and second chambers of the heart.

15. The method as recited in claim 14 further comprising sensing pressure in a chamber of the heart and wherein the step of varying the electric currents is responsive to that pressure.

16. The method as recited in claim 14 wherein the first chamber is the right ventricle; and the second chamber is the left ventricle.

17. A method for artificially contracting a heart to pump blood, that method comprising steps of:

positioning a first electromagnet outside a right atrium of the heart, wherein the first electromagnet produces a first
5 magnetic field;

positioning a second electromagnet outside a left atrium of the heart, wherein the second electromagnet produces a second magnetic field; and

selectively applying a electric currents to the first and
10 second electromagnets to produce the first and second magnetic fields which generate forces that contract the right and left atria.

18. The method as recited in claim 17 wherein the second magnet is a electromagnet; and further comprising applying electric current to the second magnet to produce the second magnetic field.

19. The method as recited in claim 17 further comprising inserting a catheter, to which a magnet is attached, into one of the first and second atria.

20. The method as recited in claim 17 further comprising inserting a catheter, to which a third electromagnet is attached, into one of the first and second atria; attaching the catheter to a wall of the heart; and selectively applying
5 an electric current to the third electromagnet to produce a third magnetic field which interacts with the first and second magnetic fields to contract the right and left atria.

21. The method as recited in claim 17 further comprising attaching an electrode to the heart; and selectively applying electric current to the electrode which stimulates the heart to contract right and left ventricles of other the heart.

22. The method as recited in claim 17 further comprising implanting an electrode in one of right and left ventricles of the heart; and selectively applying electric current to the electrode which stimulates the heart to contract the right and
5 left ventricles.

23. The method as recited in claim 17 further comprising inserting an electric coil into one of the right and left ventricles; and attaching at least one permanent magnet to the heart to generate an electric current in the electric coil as
5 the right and left ventricles contract.

24. A method for artificially contracting a heart to pump blood, that method comprising steps of:

attaching a plurality of electromagnets to an exterior surface of the heart; and

5 selectively applying electric currents to the plurality of electromagnets to produce a magnetic field from each electromagnet cause adjacent ones of the plurality of electromagnets to be attracted toward each other thereby contracting the heart to pump blood therefrom.

25. The method as recited in claim 24 wherein each one of the plurality of electromagnets comprises a conductive loop and wherein the step of selectively applying electric currents comprises passing electric current in opposite
5 directions through the loop of adjacent electromagnets.

26. A method for artificially contracting a heart to pump blood, that method comprising steps of:

placing a first band around the heart wherein the band has two ends coupled together by a first electromagnetic
5 actuator; and

selectively activating the first electromagnetic actuator to produce a magnetic field which draws the two end toward each other thereby contracting the heart.

27. An apparatus for artificially contracting a heart to pump blood, that apparatus comprising:

a first magnet on one side of a first chamber of the heart, wherein the first magnet produces a first magnetic
5 field;

a second magnet on another side of the first chamber of the heart, wherein the second magnet produces a second magnetic field; and

a controller connected to the first and second magnets
10 and selectively activating the first magnet to produce the first magnetic field which interacts with the second magnetic field to contract the first chamber of the heart.

28. The apparatus recited in claim 27 wherein the first magnet is as electromagnet; and the controller activates the first magnet by applying electric current thereto.

29. The apparatus recited in claim 28 wherein the second magnet is an electromagnet; and the controller activates the second magnet by applying electric current thereto.

30. The apparatus as recited in claim 27 wherein the first magnet is carried by a catheter inserted into a chamber of the heart.

31. The apparatus recited in claim 30 further comprising a third magnet on a side of a second chamber of the heart, wherein the third magnet produces a third magnetic field which interacts with the first magnetic field to contract the second
5 chamber of the heart.

32. The apparatus as recited in claim 31 wherein the third magnet is an electromagnet; and the controller activates the third magnet by applying electric current thereto.

33. The apparatus as recited in claim 31 wherein the first and second electromagnets are mounted on a band and couple segments of the band together.

34. An apparatus for artificially contracting a heart to pump blood, that apparatus comprising a first band placed around the heart, the band having a first gap bridged by a first electromagnetic actuator, wherein application of
5 electric current to the first electromagnetic actuator reduces the gap thereby contracting the heart.

35. The apparatus recited in claim 35 wherein the band further comprises a second gap and a second electromagnetic actuator bridging the second gap, wherein application of electric current to the second electromagnetic actuator
5 reduces the second gap thereby contracting the heart.

36. A method for artificially contracting a heart to pump blood, that method comprising steps of:

positioning a first electromagnet on one side of a first chamber of the heart, wherein application of electric current
5 to the first electromagnet produces a magnetic field;

placing a first member on another side of the first chamber of the heart, wherein the first member is attracted toward the first electromagnet by the magnetic field; and selectively applying electric current to the first
10 electromagnet to produce the magnetic field thereby attracting the first member and contracting the first chamber of the heart.

37. The method as recited in claim 36 wherein the member is a second electromagnet; and further comprising applying another electric current to the second electromagnet to produce another magnetic field.

38. The method as recited in claim 36 wherein the member is a permanent magnet.

39. The method as recited in claim 1 wherein the step of positioning a first electromagnet comprises inserting a catheter, to which the first electromagnet is attached, into a chamber of the heart.

40. The method as recited in claim 35 further comprising positioning a second member on a side of a second chamber of the heart, wherein the second member is attracted toward the first electromagnet by the magnetic field.

41. The method as recited in claim 35 further comprising
sensing a naturally occurring contraction of the heart; and
wherein selectively applying electric current to the first
electromagnet occurs in response to sensing a naturally
5 occurring contraction of the heart.

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FIG. 1

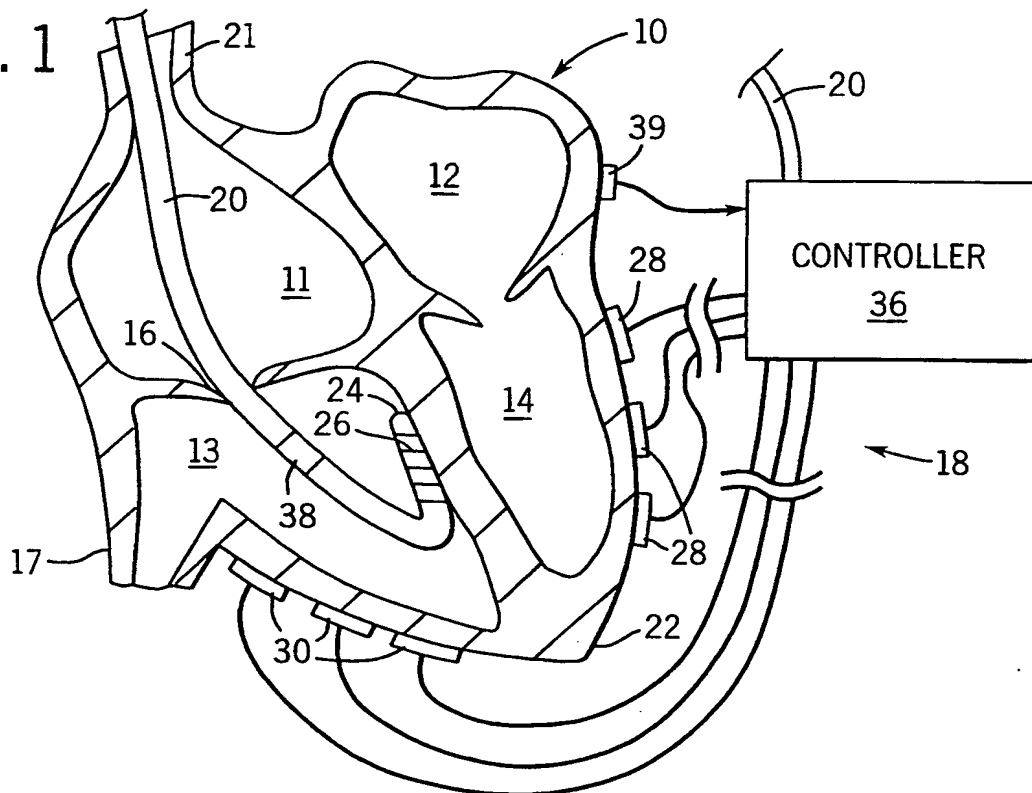
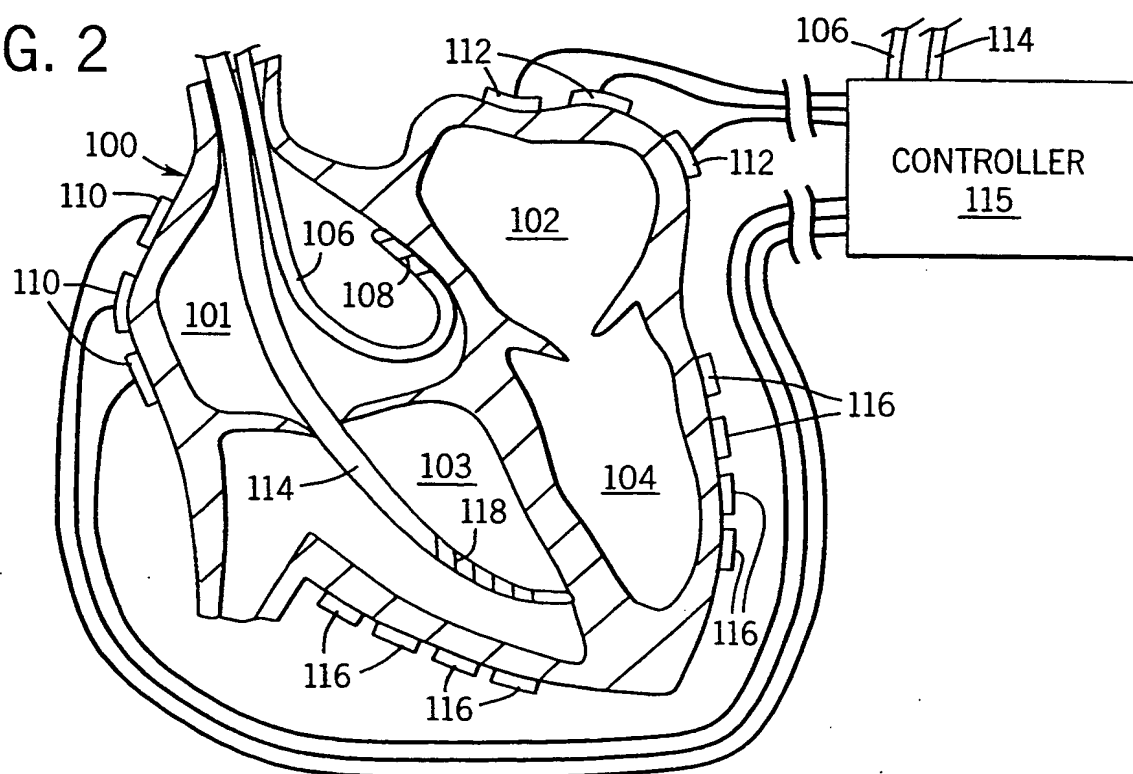


FIG. 2



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FIG. 2

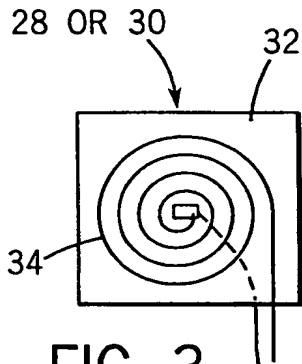
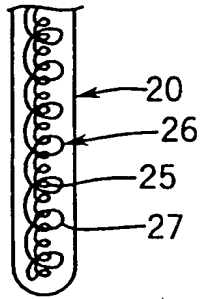


FIG. 3

FIG. 4

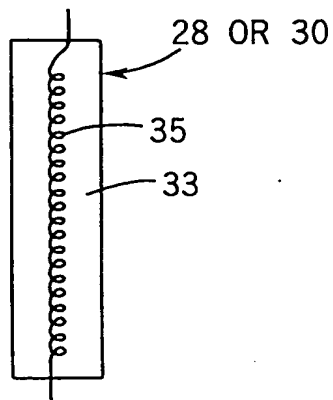


FIG. 5

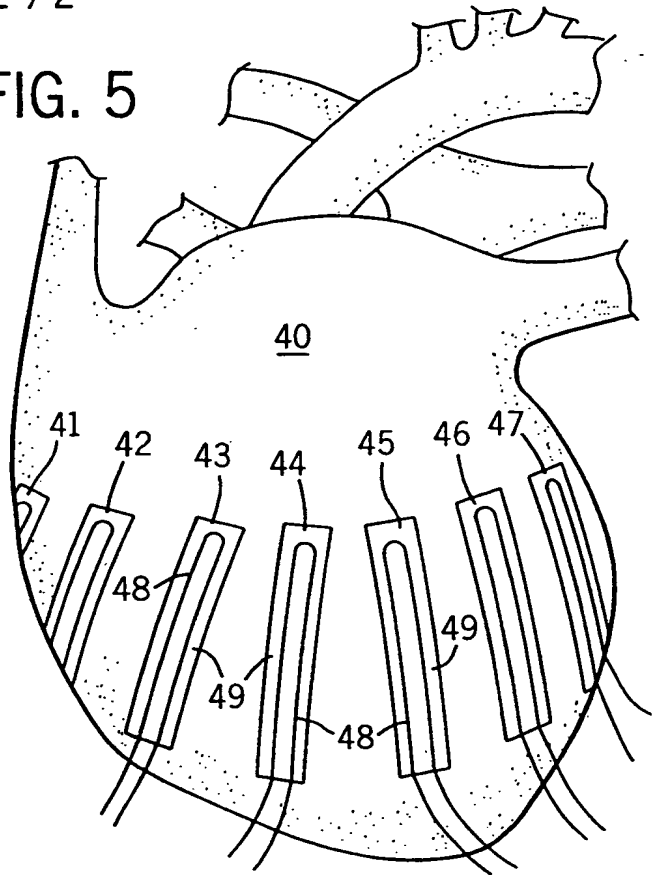
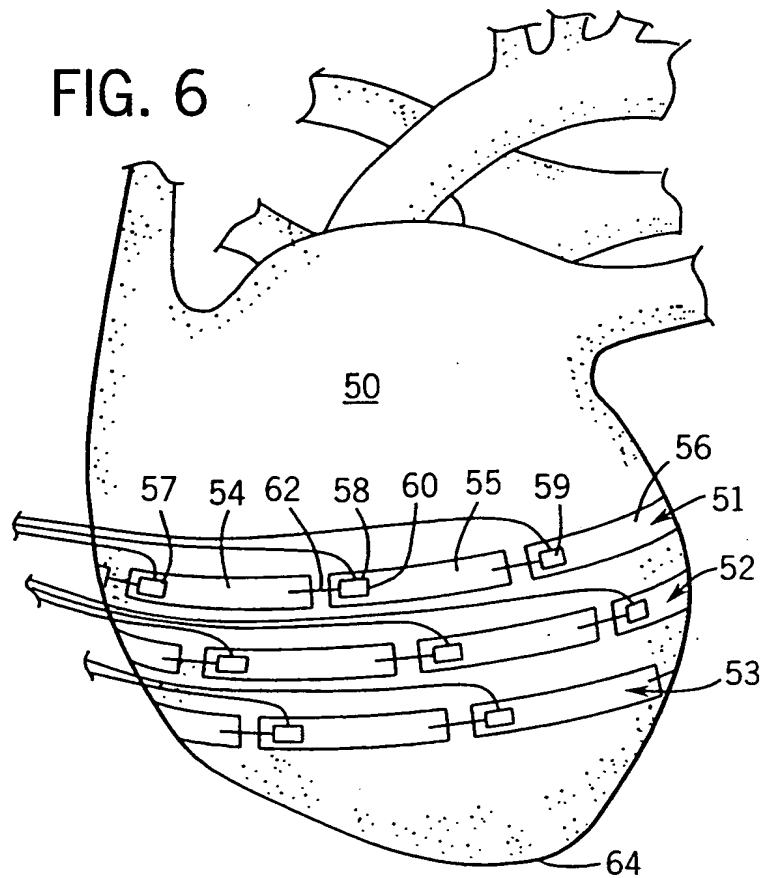


FIG. 6



PATENT COOPERATION TREATY

From the RECEIVING OFFICE

To:
**GEORGE E. HAAS
 QUARLES & BRADY
 411 EAST WISCONSIN AVENUE
 MILWAUKEE, WI 53202 4497**

PCT

COMMUNICATION IN CASES FOR WHICH
 NO OTHER FORM IS APPLICABLE

Date of mailing (day/month/year)		06 JUL 1999
Applicant's or agent's file reference 250445.9050		REPLY DUE See paragraph 1 below
International application No. PCT/US99/08591		International filing date (day/month/year) 19 APR 99
Applicant DENKER, STEPHEN		

1. ☐ REPLY DUE within _____ months/days from the above date of mailing
☐ NO REPLY DUE, however, see below _____
☒ IMPORTANT COMMUNICATION
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2. COMMUNICATION:

This is in reply to applicant's communication, filed in the Patent and Trademark Office on 26 May 1999, requesting a rectification of an obvious error in the above-identified application. At this point in international processing, such changes may be entered only if the appropriate authority, in this case, the International Searching Authority (ISA), considers the change to be a rectification of an obvious error. See PCT Rule 91. The United States Patent and Trademark Office is not the ISA for this international application and cannot make such a ruling. Therefore proposed drawing sheet 1/2 will simply be stored in the United States Receiving Office file copy and no further action will be taken.

Name and mailing address of the receiving Office Assistant Commissioner for Patent Box PCT Washington, D.C. 20231 Attn: RO/US Facsimile No. 703-305-3230	Authorized officer M. Mears, PCT Legal Office Telephone No. (703) 308-1010 <i>Edward E. Mears</i>
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E G L I
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1211 Geneva 20

VIA FACSIMILE (ORIGINAL BY MAIL)
022 733 54 28

YOUR REFERENCE:

OUR REFERENCE:
N 3975 FK

ZÜRICH,
Octobre 13, 1999

Re: PCT/US99/08591
DENKER, Stephen
Request for Publication of Refusal to Rectify Pursuant to PCT Rule 91.1(f)

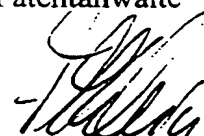
Enclosed you will find a Request for Publication of Refusal to Rectify Pursuant to PCT Rule 91.1(f), together with two attachments (Communication in cases for which no other form is applicable dated July 6, 1999 and Request for Correction of Obvious Error Pursuant to Rule 91.1(b) filed on May 26, 1999) in connection with the above-referenced PCT patent application.

Please accept this request and charge our current account No. 11543 accordingly.

Kindly acknowledge receipt and send all further communications regarding this matter to us.

Yours sincerely

R.A. EGLI & CO,
Patentanwälte



Fritz J. Klein

Enclosures

VIA FACSIMILE - 41 22 740 14 35 AND COURIER SERVICE

Applicant: DENKER, Stephen
Int'l App. No.: PCT/US99/08591
Int'l Filing Date: 19 April 1999
Priority Date: 28 April 1998
For: ELECTROMAGNETIC HEART ASSIST TECHNIQUE

REQUEST FOR PUBLICATION OF
REFUSAL TO RECTIFY PURSUANT TO PCT RULE 91.1(f)

International Bureau of WIPO
34, chemin des Colombettes
1211 Geneva 20, SWITZERLAND

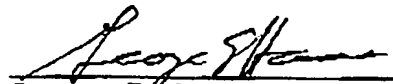
Dear Sir:

Pursuant to PCT Rule 91.1(f), request is hereby made for publication of the documents listed below with the international application to be published on or about October 28, 1999:

1. Communication in Cases for Which No Other Form is Applicable, Form PCT/RO/132, issued by the U.S. Receiving Office under mailing date of July 6, 1999, which reflects refusal to rectify the proposed drawing sheet 1/2 for the above-referenced PCT patent application.
2. Request for Correction of Obvious Error Pursuant to Rule 91.1(b) filed with the U.S. Patent and Trademark Office as the Receiving Office on May 26, 1999.

The appropriate fees are herein provided.

Respectfully submitted,


George E. Haas
Agent for Applicant

QUARLES & BRADY
411 East Wisconsin Avenue
Milwaukee, WI 53202-4497
Telephone: (414) 277-5751
Facsimile: (414) 271-3552
United States of America

IN THE UNITED STATES RECEIVING OFFICE

Applicant: DENKER, Stephen
Int'l. App. No.: PCT/US99/08591
Filing Date: 19 April 1999
For: ELECTROMAGNETIC HEART ASSIST TECHNIQUE

REQUEST FOR CORRECTION OF OBVIOUS ERROR IN
THE INTERNATIONAL APPLICATION PURSUANT TO RULE 91.1(b)

Box PCT
Attn: Examiner Hal Saunders
Commissioner of Patents and Trademarks
Washington, D.C. 20231

Sir:

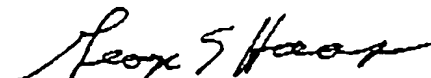
Request is hereby made for the correction of an obvious error in the international application referenced above on the following grounds:

That two sheets of drawings were filed with the International Application on April 19, 1999, which contained an obvious error wherein Figure 7 on Sheet 1/1 of the drawings was inadvertently marked as Figure 2. That said error was obvious in that on page 3 of the description of the international application marked as "Brief Description of the Drawings" reference is made to Figure 7 as "a cross-sectional view through a human heart showing an other application of the present heart stimulation technique." Therefore, it is obvious that anyone would immediately realize that nothing else could have been intended and that corrected sheet 1/1 reflecting the lower figure as being marked Figure 7 should be made.

It is specifically requested that in the event that this request for rectification of obvious error is not granted, that the corrected sheet as marked 1/1 attached hereto and incorporated herein by reference be withdrawn and that the original international filing date of 19 April 1999 (19.04.99) be maintained.

No additional fees for filing these papers are believed to be required. However, the Commissioner is hereby authorized to charge any fees which are due to Deposit Account No. 17-0055.

Respectfully submitted,



George E. Haas
Agent for Applicant

Quarles & Brady LLP
411 East Wisconsin Avenue
Milwaukee, WI 53202-4497
Tel. No. (414) 277-5709

1/2

FIG. 1

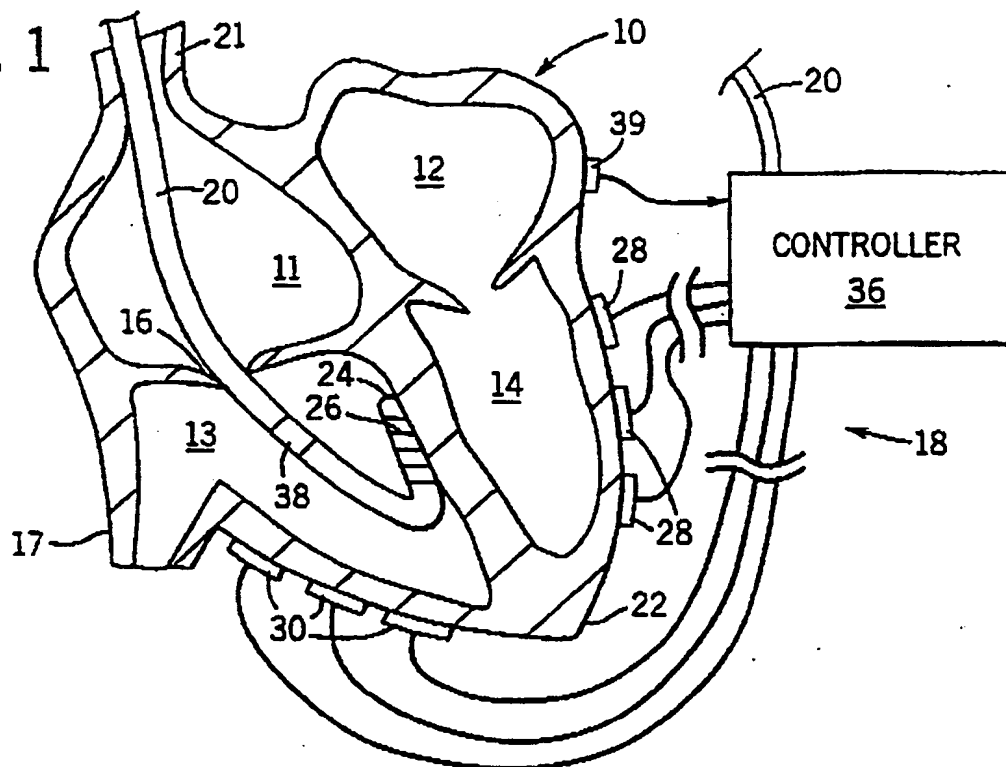
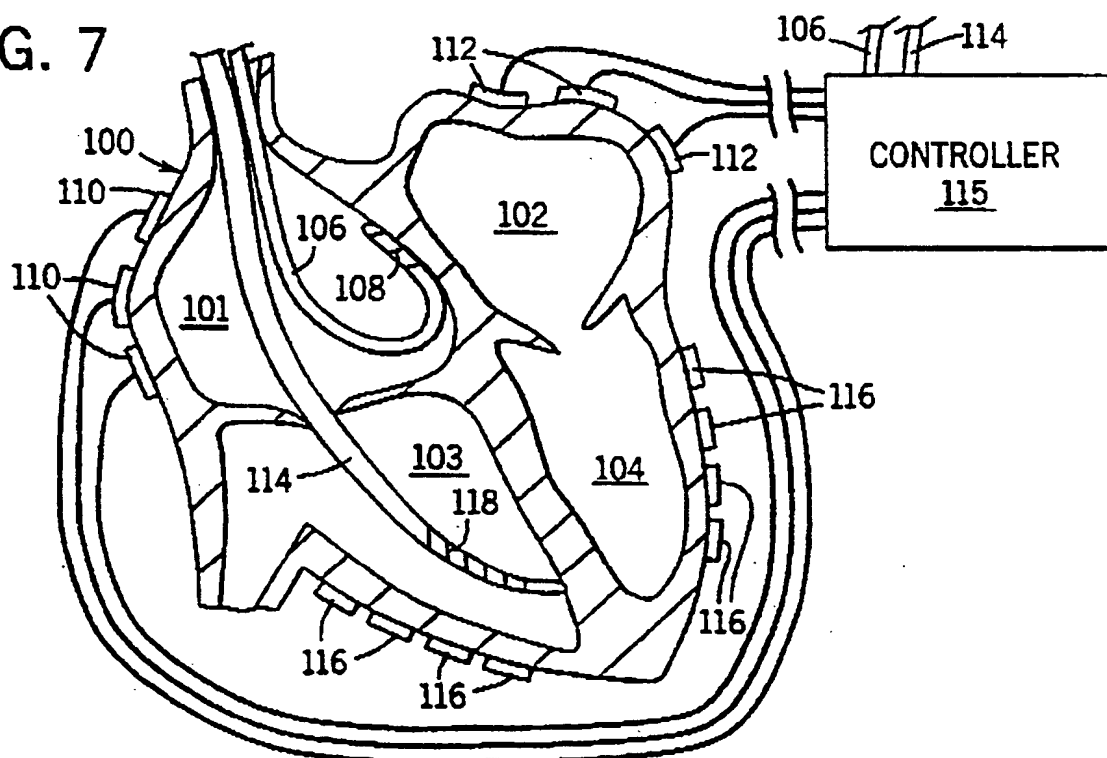


FIG. 7



2 / 2

FIG. 2

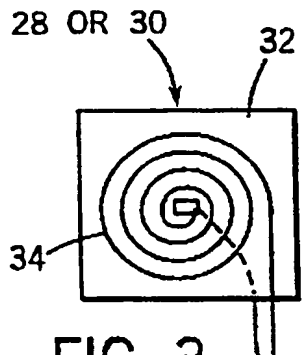
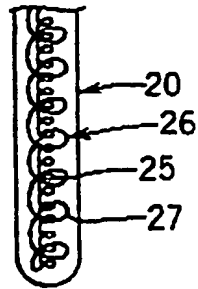


FIG. 3

FIG. 4

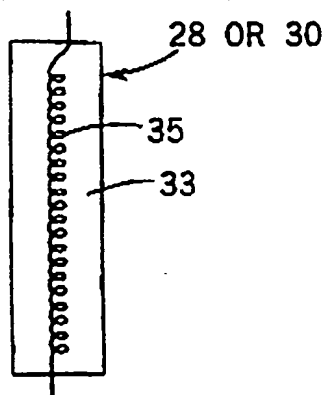


FIG. 5

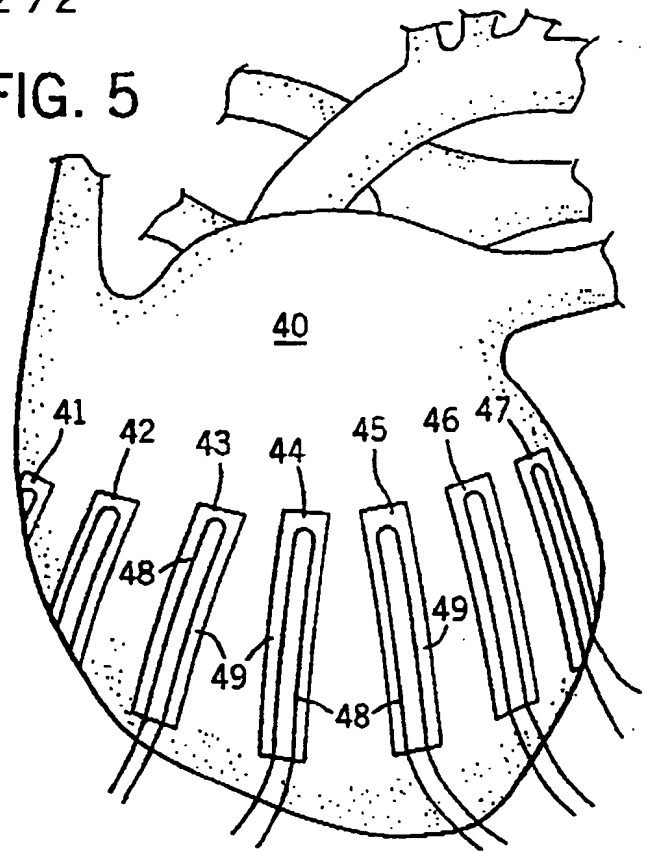
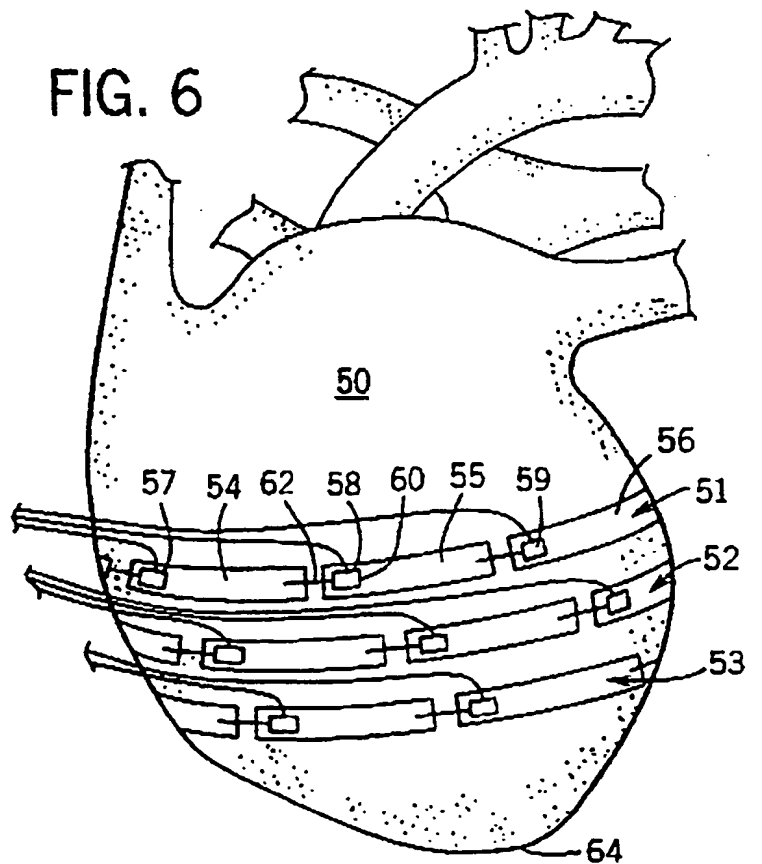


FIG. 6



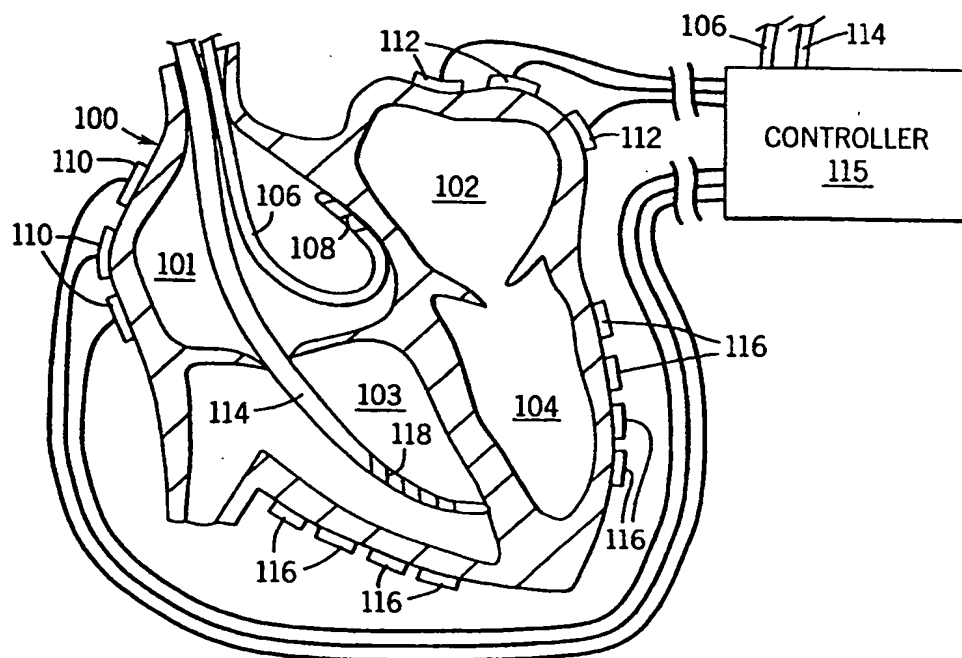
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification ⁶ : A61M 1/10	A2	(11) International Publication Number: WO 99/55399 (43) International Publication Date: 4 November 1999 (04.11.99)
(21) International Application Number: PCT/US99/08591 (22) International Filing Date: 19 April 1999 (19.04.99) (30) Priority Data: 09/067,672 28 April 1998 (28.04.98) US (71)(72) Applicant and Inventor: DENKER, Stephen [US/US]; 2130 West Columbia Drive, Mequon, WI 53092 (US). (74) Agent: HAAS, George, E.; Quarles & Brady, 411 East Wisconsin Avenue, Milwaukee, WI 53202-4497 (US).		(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG). Published <i>Without international search report and to be republished upon receipt of that report.</i>

(54) Title: ELECTROMAGNETIC HEART ASSIST TECHNIQUE



(57) Abstract

A heart can be artificially contracted to pump blood by separate electromagnets (112) to the exterior surface of the heart and implanting another electromagnet (108) inside a heart chamber. Electric currents are selectively applied to the electromagnets thereby producing magnetic fields which attract the electromagnets. That attraction generates forces which contract chambers of the heart and pump blood from those chambers. A technique for generating an electric current from a natural contraction of the heart is also described.

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ELECTROMAGNETIC HEART ASSIST TECHNIQUEBackground of the Invention

The present invention relates to artificial devices for assisting the pumping action of a heart.

Cardiac disorders often prevent the heart from being
5 able to contract properly and pump blood through the
arteries. One treatment involves surgically implanting an
artificial pacing device with electrodes attached to the
surface or inside of the heart. A controller of the implanted
pacing device periodically sends electrical pulses to the
10 electrodes which stimulate the heart muscle to contract and
pump blood from the heart chambers. This pacing action
controls the contraction of the heart thereby providing a
natural pumping action of the blood.

Individuals with more severe cardiac disease may not be
15 eligible for conventional pacing as the muscles of the heart
have deteriorated so significantly that external stimulation
will not produce sufficient pumping action. Treatment of
these individuals may involve cutting away a portion of a
ventricle of the heart and implanting an artificial pump in
20 the opening. The artificial pump supplements the heart's
pumping action. This radical solution often is the last
option available for the patient, as it permanently removes
part of the heart where the artificial pump is inserted.
Typically this treatment is used only to prolong a person's
25 life long enough to find a donor heart for transplantation.

Therefore, it is desirable to provide a technique for
artificially inducing contraction of a heart in individuals
with significant muscle deterioration, where the procedure is
less invasive and less radical than the surgical implantation
30 of an artificial pump.

Summary of the Invention

A general object of the present invention is to provide a technique and apparatus for artificially contracting chambers of the heart to pump blood in situations where conventional cardiac pacing is insufficient. This invention enhances the cardiac output of the heart.

Another object of the present invention is to utilize electromagnets to produce magnetic fields which cause contraction of the heart chambers.

10 A further object of the present invention is to utilize a plurality of electromagnets and control the application of electric current individually to each one so as to produce a controlled contraction which optimizes the pumping of blood.

These and other objectives are satisfied by a method for artificially contracting the heart in an animal to pump blood. A first magnet is attached on one side of a first chamber of the heart, wherein the first magnet produces a first magnetic field. A second magnet is attached on another side of the first chamber, wherein the second magnet produces a second magnetic field. In the preferred embodiment of the present method, both of these magnets are electromagnet coils which produce a magnetic field when an electric current is sent through the coils.

20 To contract the heart, the first magnet is selectively activated to produce the first magnetic field which interacts with the second magnetic field. That interaction generates a force which contract the first chamber of the heart.

The present method can be used to contract either one or both of the right and left ventricles of the heart. In that case, it is preferred to attach separate electromagnet coils to the exterior surface of the heart outside both ventricles. Another coil on a catheter is inserted into one of the

ventricles and secured to a wall of the heart. Pulses of electric current are applied to the different coils to produce magnetic fields which generate forces that attract the coils to each other and contract the right and left
5 ventricles.

Brief Description of the Drawings

FIGURE 1 is a cross-sectional view of a human heart to which the present technique is being applied;

FIGURE 2 is a detailed representation of a catheter
10 shown in Figure 1;

FIGURE 3 illustrates one of the external electromagnetic coils used in Figure 1;

FIGURE 4 illustrates an alternative embodiment of an external electromagnetic coil;

15 FIGURE 5 shows human heart with electromagnetic coils applied for a second embodiment of the present invention;

FIGURE 6 shows human heart with electromagnetic coils applied for a third embodiment of the present invention; and

FIGURE 7 is a cross-sectional view through a human heart
20 showing another application of the present heart stimulation technique.

Detailed Description of the Invention

With initial reference to Figure 1, a human heart 10 has a right atrium 11, a left atrium 12, a right ventricle 13 and
25 a left ventricle 14. Blood returning to the heart 10 from the body flows through the superior and inferior vena cava and passes into the right atrium 11 wherefrom it is pumped through the tricuspid valve 16 and into the right ventricle 13. Contraction of the right ventricle 13 causes the
30 tricuspid valve 16 to close in response to the generated

pressure and the blood to flow outward through the pulmonary arteries. After having passed through the lungs, oxygenated blood returns to the left atrium 12, where it is boosted into the left ventricle and thereafter pumped to the body through
5 the aorta.

For hearts which are unable to pump an adequate amount of blood to the body, an artificial contraction assist device 18 is implanted into the patient. Using known procedures, a catheter 20 is introduced into any of several veins and
10 advanced through the superior vena cava 21 into the right atrium 11. Further advancement causes the catheter 20 to pass through the tricuspid valve 16 and into the right ventricle 13. This procedure is similar to ones used in implanting catheters for conventional cardiac pacing devices. In those
15 procedures, the catheter electrode tip ordinarily is wedged into the interior wall of the right ventricle pointing toward the apex 22.

The same general procedure may be followed to introduce the electromagnetic stimulation catheter 20 according to the
20 present invention. That catheter 20 is preferably of a steerable type such as the one disclosed in U.S. Patent No. 5,674,271. The catheter 20 has electrical wires running there through to tip 24 where the wires connect to a coil 26 wound in a spiral lengthwise along the catheter as shown in
25 Figure 2. Specifically, the coil 26 comprises an inner winding 25 and an outer winding 27 wound in the opposite direction coaxially around the inner winding. Because the inner and out windings 25 and 27 are wound in opposite directions, their individual electromagnetic fields add
30 together. The steerable nature of the catheter 20 allows coil 26 to be placed against the septum between the two ventricles 13 and 14 as shown in Figure 1. The tip 24 may

include a corkscrew-like element for imbedding into the septum to secure the catheter in place. Alternatively, other techniques commonly utilized with pacing catheters may be employed to secure the catheter tip.

5 A plurality of electrical coils 28 are applied to the exterior surface of the heart outside the left ventricle 14. Another plurality of electrical coils 30 are applied to the exterior surface of the right ventricle 13. As shown in Figure 3, each electrical coil 28 and 30 preferably comprise
10 a flexible substrate 32 which is applied to the exterior surface of the heart 10 with surgical adhesive or stitches. An electrical spiral shaped coil 34 is on the substrate 32 and may be sandwiched between two layers of the substrate. The coil 34 can be formed by a wire that is wound in a spiral
15 on the substrate surface or can be formed by a thin layer of electrically conductive material that has been etched to form the spiral pattern. Electrical wires are connected to each end of the coil 34. Alternatively, the coils for one side of the heart could be formed on a single flexible substrate.

20 Other forms of electrical coils can be utilized with the present heart assistance technique. For example as depicted in Figure 4, the external coils 28 and 20 may be formed by an elongated spiral winding 35 carried by a strip-like flexible substrate 32. The flexible substrate 32 is applied in a
25 generally vertical orientation to the exterior surface of the heart 10 and held in place with surgical adhesive or stitches.

The wires in the catheter 20 and from the electrical coils 28 and 30 extend to a controller 36. This controller is similar to prior cardiac pacing devices which produce
30 electrical pulses applied to electrodes that stimulate a responsive contraction of the heart muscles. However, the present controller 36 applies pulses of electric current

6

through the various coils to generate magnetic fields that cause the coils to be attracted to each other in a controlled manner. Specifically, when a contraction of the ventricles 13 and 14 is desired, the controller 36 applies an electrical pulse of direct current, having a duration equal to that of the desired contraction, to the coil 26 of catheter 20. During that catheter pulse, pulses of direct current also are applied to the external electrical coils 28 and 30. The electric currents applied to the catheter coil 26 and the external electric coils 28 and 30 produce electromagnetic fields about those coils. Due to the direction of the direct current through each coil, the magnetic fields are polarized so that the external coils 28 and 30 are attracted toward the internal coil 26 of catheter 20. This magnetic attraction contracts the right and/or left ventricles 13 and 14 in much the same manner as though the heart muscles contracted the ventricles.

Typically the controller also receives an input signal from a plurality of sensors, collectively represented by sensor 39, which indicate when a natural contraction of the heart is occurring. The controller 36 responds to that signal by applying electrical pulses to the coils 26, 28 and 30. Usually the patient has some cardiac function which is a fraction (e.g. 50%) of the normal function. In this case the electrical pulses will be timed and applied at the end of the natural heart contraction to compress the ventricles the remaining amount to achieve full cardiac output. Thus the present technique increases the efficiency of a defective heart.

The controller can be programmed so that the external coils 28 and 30 for each ventricle 14 and 13 are pulsed separately or simultaneously. The magnitude of electrical

current applied to each coil 26, 28 and 30 can be regulated independently to produce the desired amount of heart contraction of each ventricle 13 and 14. For example, the controller 36 can vary the current magnitudes in response to sensing the pressure in the right ventricle by means of a pressure sensor 38 positioned on the catheter 20. The external coils 28 and 30 for a given ventricle may be pulsed in unison or sequentially pulsed by the controller 36 to squeeze the ventricle in a progressive manner from the apex 22 to the base or outflow area to force the blood from the ventricle through the aorta.

With reference to Figure 5, an alternative implementation of the present invention utilizes a plurality of external electromagnet coils 41, 42, 43, 44, 45, 46 and 47 with additional coils similarly positioned on the rear side of the heart 40. This embodiment eliminates the need for a catheter with a coil inside the heart. Each external electromagnet coil 41-47 comprises at least one loop 48 of an electrical conductor attached to a flexible substrate 49 which is applied to the exterior surface of the heart 40 with surgical adhesive or stitches.

To contract the heart 40, electric current is applied in opposite directions through adjacent coils 41-47. For example, the electric current may flow in the clockwise direction through the odd numbered coils 41, 43, 45 and 47 and flow counter-clockwise in the even numbered coils 42, 44 and 46. This produces oppositely poled electromagnetic fields in adjacent coils resulting in forces which cause attraction of the adjacent the coils. As the coils come toward each other the exterior wall of the heart 40 becomes pleated thereby contracting the ventricles. Similar electromagnet coils may be

applied to the upper portion of the heart to assist contraction of the atria.

Referring to Figure 6, a third embodiment of the present cardiac assistance technique applies a plurality of external bands 51, 52 and 53 around the ventricular region of the heart 50. Each band 51-53 is formed by a series of segments coupled having ends coupled together by electromagnetic actuators. For example, the first band 51 has segments 54, 55 and 56 with other segments extending around the rear of the heart 50. Each actuator 57, 58 and 59 of the first band 51 comprises a solenoid coil attached to one segment of the band with an armature connected to another segment. For example, actuator 58 has a solenoid coil 60 connected to band segment 55 and an armature 62 coupled to band segment 54. The bands 51-53 may have various numbers of segments and corresponding numbers of actuators. At the very least a band has a single segment with one actuator coupling the ends of that segment together. In addition the number of bands applied to the heart may vary.

To produce contraction of the ventricles of the heart 50, the controller applies electric current simultaneously to all of the actuators of a given band 51-53. For the first band 51 actuators 57, 58 and 59 will be energized simultaneously. This action creates electromagnetic fields which draw the armatures into the solenoid coils of the actuators 57-59, thereby pulling the band segments 54-56 closer together. Thus the perimeter of the band 51 is reduced, contracting the heart 50. The other bands 52 and 53 may be contracted at the same time as the first band 51 or the bands may be energized sequentially starting with the band 53 closest to the apex 64. This latter action produces a progressive contraction of the heart 50 toward the outflow area to force the blood from the ventricle through the aorta.

The present invention utilizes the electromagnetic attraction to assist the heart 10 in its natural pumping action. This technique, which does not require cutting the heart, is less invasive than previous artificial pump assisted techniques and replicates the natural pumping action of the heart. By utilizing a programmable controller 36, magnitude of the electromagnetic fields can be varied, thereby configuring the cardiac contraction force for each patient.

Moreover, the circulating blood does not leave the heart to be pumped as it does with current artificial pumps. Therefore, the potential for bleeding from the connecting in flow and out flow sites with current artificial pumps is eliminated. There is also less likelihood of blood clots forming because blood does not need to be in contact with artificial pump surfaces.

Figure 7 illustrates an alternative application of the present technique for patients with atria that do not contract fully. Such a condition also may interfere with the production of electrical pulses that are conducted by the heart to the atrioventricular node to produce regular contraction of the ventricles. The lack of full atrial contraction results in loss of the primer pump action (so-called "atrial kick") and the atrial contribution to ventricular function. Loss of atrial contraction can also result in blood clot formation in the atria and subsequent emboli, e.g. embolic stroke.

To enhance the pumping action of the atria, a catheter 106 with a spiral coil 108 near its tip is positioned within the right atrium 101 against the wall of the left atrium 102. A plurality of electrical coils 110 are attached to the exterior surface of the heart 100 outside the right atrium and a second plurality of electric coils 112 are similarly applied to the exterior of the left atrium. Each of these external

electric coils 110 and 112 have a structure similar to that described previously.

A conventional catheter 114, as used with cardiac pacing devices, is inserted through the right atrium 101 into the
5 right ventricle 103 and positioned adjacent to the septum between the right and left ventricles 103 and 104. In this application of the present invention, the atrioventricular (AV) node is disabled either with pharmaceuticals or by ablation techniques. As a result, electrical signals
10 produced for the atria do not travel to the ventricular region of the heart and conventional cardiac pacing must be employed to stimulate ventricular contractions.

A controller 115 is connected to the two catheters 106 and 114 and to the two plurality of external electrodes 110
15 and 112. To produce contraction of the atria 101 and 104 the pacer applies electrical pulses to the electrical coil 108 within catheter 106 and to each of the external electrical coils 110 and 112. The electrical currents applied to these coils create electromagnetic fields which result in
20 contraction of the right and/or left atria in a manner similar to that previously described with respect to the ventricles in the Figure 1 embodiment. By producing the electrical pulses at regular intervals, normal atrium contractions can be produced, and timed to augment ventricular function.

25 Because the AV node has been disabled the contractions of the atria do not produce the normal contractions of the ventricles 103 and 104. Instead, the controller 115 applies a conventional pacing pulse to the tip of the ventricular catheter 114 which stimulates the muscles of the heart to
30 contract the ventricles and pump blood therefrom. The controller 115 times the atrial and ventricular contractions to replicate those of a normal heart, i.e. electromagnetic

contraction of the atria can be specifically timed to precede the stimulation of the ventricles.

As the pumping force of the atria 101 and 102 is significantly less than that required for the ventricles 103 and 104. The use of an internal catheter 106 may not be required in all situations. As a consequence the atria pumping action may be achieved by merely the sets of external coils 110 and 112 and creating the properly poled magnetic fields from those coils to cause contraction of both atria.

Because the pumping of the ventricles 103 and 104 utilizes the normal muscle contraction of the heart in this latter embodiment, it is possible to produce some of the electrical power required by the controller 115 from the ventricular contractions. For this purpose a plurality of permanent magnets 116 can be attached to the exterior surface of the heart adjacent the right and left ventricles 103 and 104. In this enhancement, the ventricular catheter 114 has an additional electrical coil 118 adjacent its tip. As the normal ventricle contraction occurs the permanent magnets 116 move with respect to the catheter coil 118. The movement of the electric field produced by the permanent magnets with respect to the catheter coil 118 will generate an electrical current which can be utilized by the controller 115 to power the atrial stimulation.

The foregoing description is directed primarily to preferred embodiments of the invention. Although some attention was given to various alternatives within the scope of the invention, it is anticipated that skilled artisans will likely realize additional alternatives that are now apparent from the disclosure of those embodiments. Accordingly, the scope of the invention should be determined from the following claims and not limited by the above disclosure.

CLAIMS

I claim:

1. A method for artificially contracting a heart to pump blood, that method comprising steps of:

positioning a first magnet on one side of a first chamber of the heart, wherein the first magnet produces a first
5 magnetic field;

placing a second magnet on another side of the first chamber of the heart, wherein the second magnet produces a second magnetic field; and

selectively activating the first magnet to produce the
10 first magnetic field which interacts with the second magnetic field to contract the first chamber of the heart.

2. The method as recited in claim 1 wherein the first magnet is an electromagnet and the step of selectively activating the first magnet comprising applying electric current to the electromagnet to produce the first magnetic
5 field.

3. The method as recited in claim 2 wherein the second magnet is an electromagnet; and further comprising applying electric current to the second magnet to produce the second magnetic field.

4. The method as recited in claim 1 wherein the step of positioning a first magnet comprises inserting a catheter, to which the first magnet is attached, into a chamber of the heart and attaching the catheter to a wall of the heart.

5. The method as recited in claim 1 wherein the step of positioning a first magnet comprises inserting a catheter, to which the first magnet is attached, into a chamber of the heart.

6. The method as recited in claim 5 wherein the step of positioning a second magnet comprises attaching the second magnet to an external surface of the heart.

7. The method as recited in claim 5 further comprising positioning a third magnet on a side of a second chamber of the heart, wherein the third magnet produces a third magnetic field which interacts with the first magnetic field to contract the second chamber of the heart.

8. The method as recited in claim 1 further comprising positioning an electrode adjacent to the heart; and selectively applying electric current to the electrode which stimulates the heart to contract a chamber of the heart other
5 than the first chamber.

9. The method as recited in claim 1 further comprising sensing a naturally occurring contraction of the heart; and wherein selectively activating the first magnet occurs in response to sensing a naturally occurring contraction of the heart.

10. The method as recited in claim 1 wherein the step of positioning a first magnet comprises placing a first band around the heart wherein the first band has ends coupled together by a first electromagnetic actuator in which
5 application of electric current to the first electromagnetic actuator causes a reduction in a perimeter of the first band and contraction of the heart.

11. The method as recited in claim 10 wherein the step of positioning a second magnet comprises placing a second band around the heart wherein the second band has ends coupled together by a second electromagnetic actuator in which
5 application of electric current to the second electromagnetic actuator causes a reduction in a perimeter of the second band and contraction of the heart.

12. The method as recited in claim 1 wherein the steps of positioning a first magnet and positioning a second magnet comprise placing a band around the heart wherein the band includes a plurality of segments, the first magnet comprises a
5 first electromagnetic actuator which couples two of the plurality of segments and the second magnet comprises a second electromagnetic actuator which couples two of the plurality of segments; and wherein application of electric current to the first and second electromagnetic actuators causes a reduction in a perimeter of the band and contraction of the heart.

13. A method for artificially contracting a heart to pump blood, wherein the heart has at least first and second chambers, that method comprising steps of:

positioning a first electromagnet adjacent to the heart
5 outside the first chamber to produce a first magnetic field;

positioning a second electromagnet adjacent to the heart
outside the second chamber to produce a second magnetic field.

implanting a third electromagnet inside one of the first
and second chambers to produce a third magnetic field; and

10 selectively applying electric currents to the first,
second and third electromagnets to produce the first, second
and third magnetic fields which interact to contract the first
and second chambers of the heart.

14. The method as recited in claim 13 further comprising varying the electric currents to control magnitudes of the first, second and third magnetic fields and thereby control contraction of the first and second chambers of the heart.

15. The method as recited in claim 14 further comprising sensing pressure in a chamber of the heart and wherein the step of varying the electric currents is responsive to that pressure.

16. The method as recited in claim 14 wherein the first chamber is the right ventricle; and the second chamber is the left ventricle.

17. A method for artificially contracting a heart to pump blood, that method comprising steps of:

positioning a first electromagnet outside a right atrium of the heart, wherein the first electromagnet produces a first magnetic field;

positioning a second electromagnet outside a left atrium of the heart, wherein the second electromagnet produces a second magnetic field; and

selectively applying a electric currents to the first and second electromagnets to produce the first and second magnetic fields which generate forces that contract the right and left atria.

18. The method as recited in claim 17 wherein the second magnet is a electromagnet; and further comprising applying electric current to the second magnet to produce the second magnetic field.

19. The method as recited in claim 17 further comprising inserting a catheter, to which a magnet is attached, into one of the first and second atria.

20. The method as recited in claim 17 further comprising inserting a catheter, to which a third electromagnet is attached, into one of the first and second atria; attaching the catheter to a wall of the heart; and selectively applying
5 an electric current to the third electromagnet to produce a third magnetic field which interacts with the first and second magnetic fields to contract the right and left atria.

21. The method as recited in claim 17 further comprising attaching an electrode to the heart; and selectively applying electric current to the electrode which stimulates the heart to contract right and left ventricles of other the heart.

22. The method as recited in claim 17 further comprising implanting an electrode in one of right and left ventricles of the heart; and selectively applying electric current to the electrode which stimulates the heart to contract the right and
5 left ventricles.

23. The method as recited in claim 17 further comprising inserting an electric coil into one of the right and left ventricles; and attaching at least one permanent magnet to the heart to generate an electric current in the electric coil as
5 the right and left ventricles contract.

24. A method for artificially contracting a heart to pump blood, that method comprising steps of:

attaching a plurality of electromagnets to an exterior surface of the heart; and

5 selectively applying electric currents to the plurality of electromagnets to produce a magnetic field from each electromagnet cause adjacent ones of the plurality of electromagnets to be attracted toward each other thereby contracting the heart to pump blood therefrom.

25. The method as recited in claim 24 wherein each one of the plurality of electromagnets comprises a conductive loop and wherein the step of selectively applying electric currents comprises passing electric current in opposite
5 directions through the loop of adjacent electromagnets.

26. A method for artificially contracting a heart to pump blood, that method comprising steps of:

placing a first band around the heart wherein the band has two ends coupled together by a first electromagnetic
5 actuator; and

selectively activating the first electromagnetic actuator to produce a magnetic field which draws the two end toward each other thereby contracting the heart.

27. An apparatus for artificially contracting a heart to pump blood, that apparatus comprising:

5 a first magnet on one side of a first chamber of the heart, wherein the first magnet produces a first magnetic field;

a second magnet on another side of the first chamber of the heart, wherein the second magnet produces a second magnetic field; and

10 a controller connected to the first and second magnets and selectively activating the first magnet to produce the first magnetic field which interacts with the second magnetic field to contract the first chamber of the heart.

28. The apparatus recited in claim 27 wherein the first magnet is as electromagnet; and the controller activates the first magnet by applying electric current thereto.

29. The apparatus recited in claim 28 wherein the second magnet is an electromagnet; and the controller activates the second magnet by applying electric current thereto.

30. The apparatus as recited in claim 27 wherein the first magnet is carried by a catheter inserted into a chamber of the heart.

31. The apparatus recited in claim 30 further comprising a third magnet on a side of a second chamber of the heart, wherein the third magnet produces a third magnetic field which interacts with the first magnetic field to contract the second
5 chamber of the heart.

32. The apparatus as recited in claim 31 wherein the third magnet is an electromagnet; and the controller activates the third magnet by applying electric current thereto.

33. The apparatus as recited in claim 31 wherein the first and second electromagnets are mounted on a band and couple segments of the band together.

34. An apparatus for artificially contracting a heart to pump blood, that apparatus comprising a first band placed around the heart, the band having a first gap bridged by a first electromagnetic actuator, wherein application of
5 electric current to the first electromagnetic actuator reduces the gap thereby contracting the heart.

35. The apparatus recited in claim 35 wherein the band further comprises a second gap and a second electromagnetic actuator bridging the second gap, wherein application of electric current to the second electromagnetic actuator
5 reduces the second gap thereby contracting the heart.

36. A method for artificially contracting a heart to pump blood, that method comprising steps of:

positioning a first electromagnet on one side of a first chamber of the heart, wherein application of electric current
5 to the first electromagnet produces a magnetic field;

placing a first member on another side of the first chamber of the heart, wherein the first member is attracted toward the first electromagnet by the magnetic field; and selectively applying electric current to the first
10 electromagnet to produce the magnetic field thereby attracting the first member and contracting the first chamber of the heart.

37. The method as recited in claim 36 wherein the member is a second electromagnet; and further comprising applying another electric current to the second electromagnet to produce another magnetic field.

38. The method as recited in claim 36 wherein the member is a permanent magnet.

39. The method as recited in claim 1 wherein the step of positioning a first electromagnet comprises inserting a catheter, to which the first electromagnet is attached, into a chamber of the heart.

40. The method as recited in claim 35 further comprising positioning a second member on a side of a second chamber of the heart, wherein the second member is attracted toward the first electromagnet by the magnetic field.

41. The method as recited in claim 35 further comprising sensing a naturally occurring contraction of the heart; and wherein selectively applying electric current to the first electromagnet, occurs in response to sensing a naturally
5 occurring contraction of the heart.

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FIG. 1

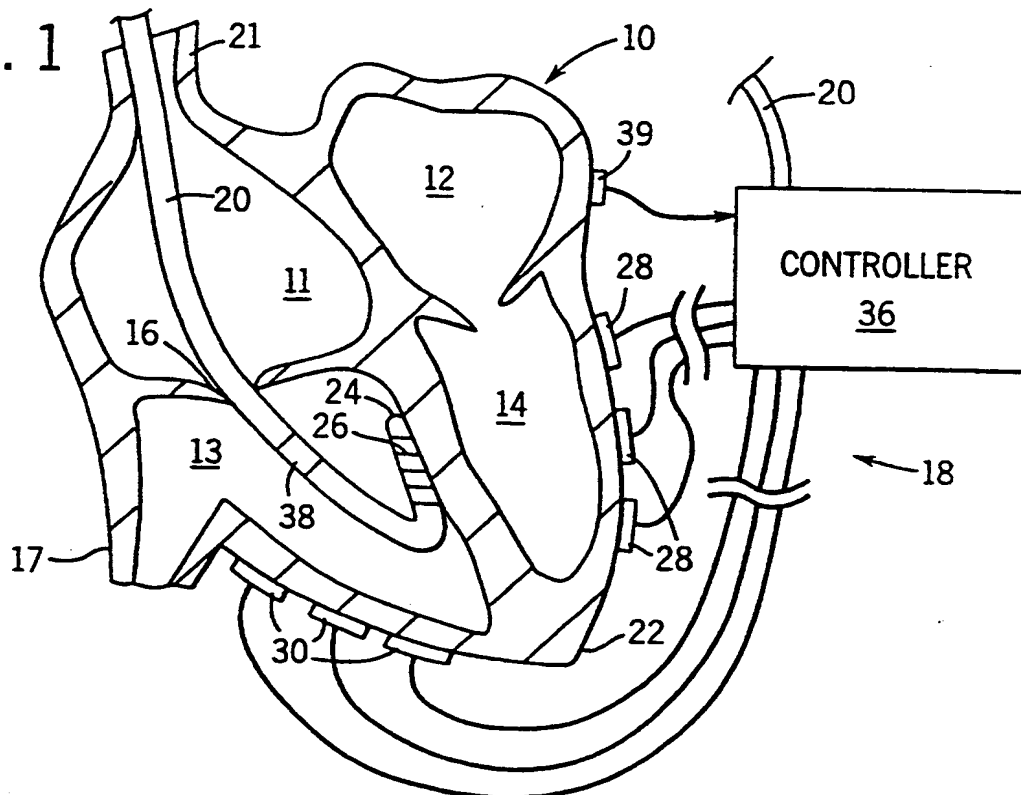
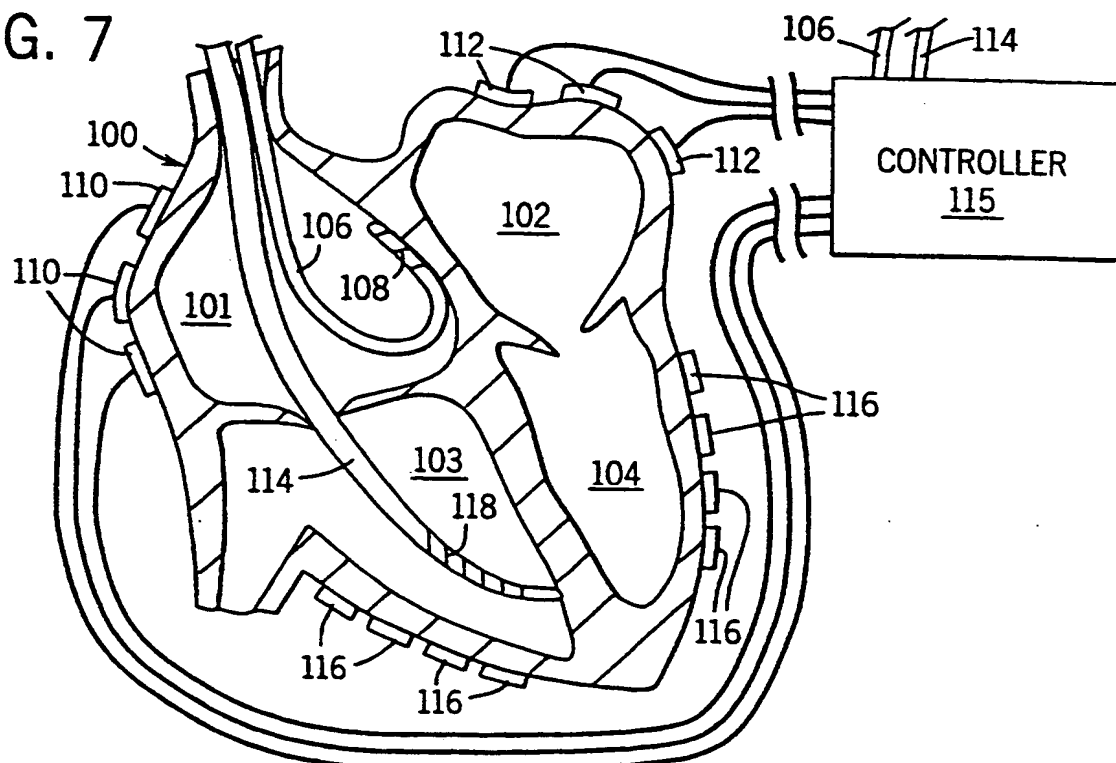


FIG. 7



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FIG. 2

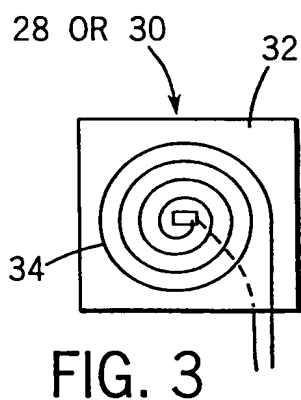
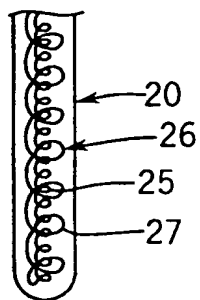


FIG. 4

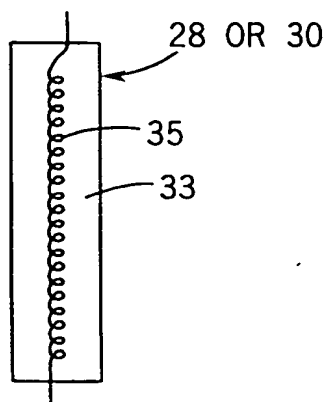


FIG. 5

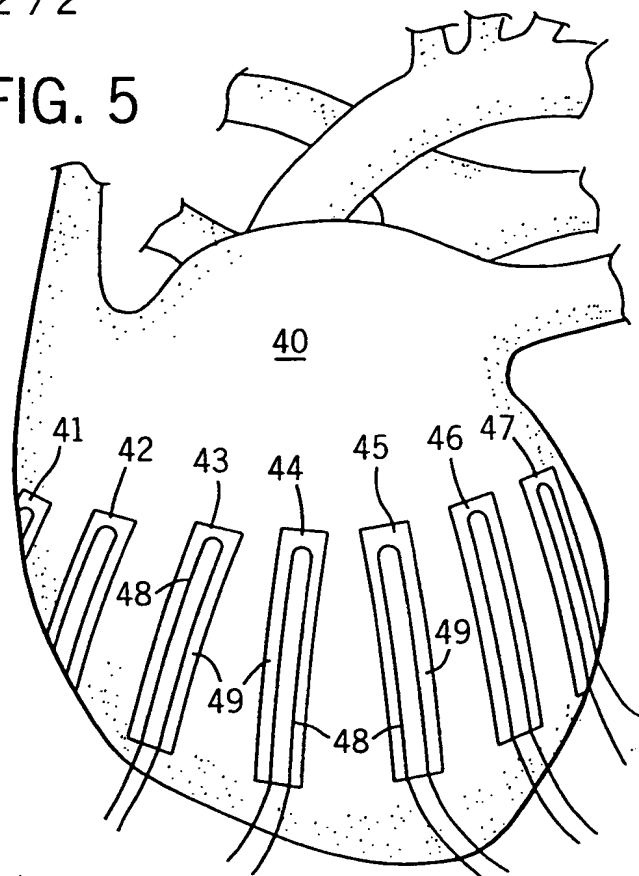
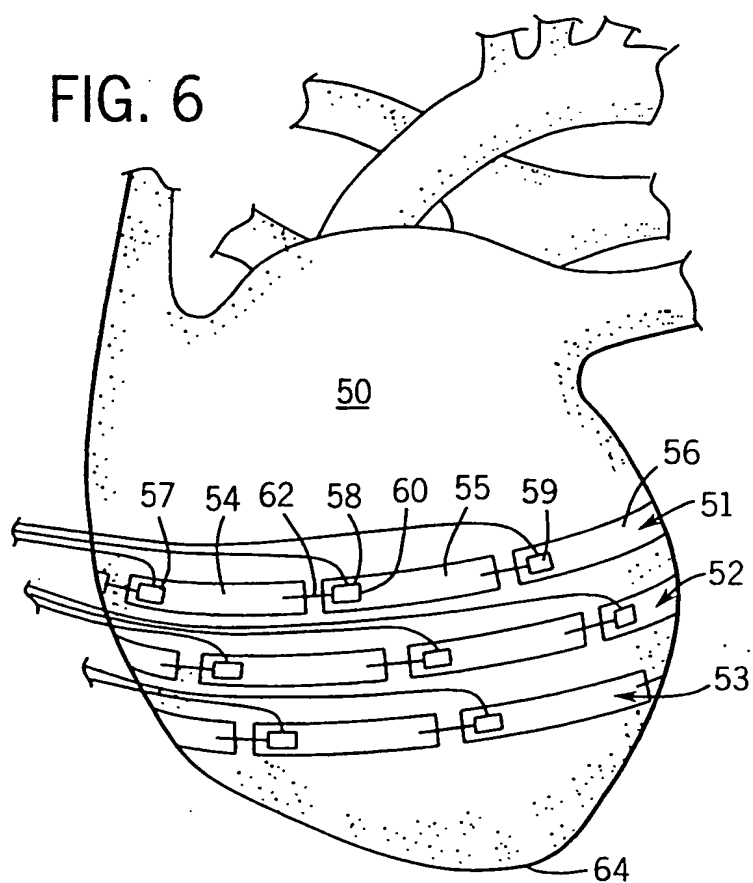


FIG. 6



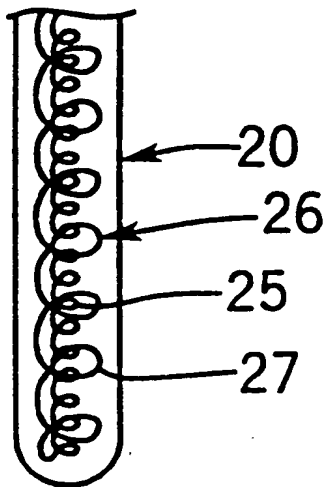
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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

<p>(51) International Patent Classification ⁶ : A61M 1/10</p>	<p>A3</p>	<p>(11) International Publication Number: WO 99/55399</p> <p>(43) International Publication Date: 4 November 1999 (04.11.99)</p>
<p>(21) International Application Number: PCT/US99/08591</p> <p>(22) International Filing Date: 19 April 1999 (19.04.99)</p> <p>(30) Priority Data: 09/067,672 28 April 1998 (28.04.98) US</p> <p>(71)(72) Applicant and Inventor: DENKER, Stephen [US/US]; 2130 West Columbia Drive, Mequon, WI 53092 (US).</p> <p>(74) Agent: HAAS, George, E.; Quarles & Brady, 411 East Wisconsin Avenue, Milwaukee, WI 53202-4497 (US).</p>		<p>(81) Designated States: AE, AL, AM, AT, AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, DE, DK, EE, ES, FI, GB, GD, GE, GH, GM, HR, HU, ID, IL, IN, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SL, TJ, TM, TR, TT, UA, UG, UZ, VN, YU, ZA, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SL, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, CY, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, GW, ML, MR, NE, SN, TD, TG).</p> <p>Published <i>With international search report. Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.</i></p> <p>(88) Date of publication of the international search report: 9 March 2000 (09.03.00)</p>

(54) Title: ELECTROMAGNETIC HEART ASSIST TECHNIQUE



(57) Abstract

A heart can be artificially contracting to pump blood by separate electromagnets (112) to the exterior surface of the heart and implanting another electromagnet (108) inside a heart chamber. Electric currents are selectively applied to the electromagnets thereby producing magnetic fields which attract the electromagnets. That attraction generates forces which contract chambers of the heart and pump blood from those chambers. A technique for generating an electric current from a natural contraction of the heart also is described.

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/08591

A. CLASSIFICATION OF SUBJECT MATTER

IPC 6 A61M1/10

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC 6 A61M

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

Electronic data base consulted during the international search (name of data base and, where practical, search terms used)

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	DE 43 14 269 A (G BERG) 3 November 1994 (1994-11-03) column 3, line 15 - line 46 figures 1-3	27-29
A	---	30
A	WO 96 04945 A (J ROYALTY) 22 February 1996 (1996-02-22) abstract figures 1-3	27
A	---	34
	EP 0 280 301 A (HEILMAN ET AL.) 31 August 1988 (1988-08-31) column 15, line 15 - line 29; figure 11 ---	
	-/--	

☒ Further documents are listed in the continuation of box C.

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Date of the actual completion of the international search

7 January 2000

Date of mailing of the international search report

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INTERNATIONAL SEARCH REPORT

International Application No
PCT/US 99/08591

C.(Continuation) DOCUMENTS CONSIDERED TO BE RELEVANT		
Category *	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4 621 617 A (SHARMA DEVENDRA N) 11 November 1986 (1986-11-11) column 3, line 16 - line 27 column 4, line 17 - line 50 figures 1-3 ----	34
A	US 4 809 676 A (FREEMAN) 7 March 1989 (1989-03-07) column 6, line 4-26 column 7, line 1 - line 23 figures 1,2 ----	34
A	US 5 383 840 A (HEILMAN ET AL) 24 January 1995 (1995-01-24) abstract -----	34

INTERNATIONAL SEARCH REPORT

Int. l. application No.

PCT/US 99/ 08591

B x I Observations where certain claims were found unsearchable (Continuation of item 1 of first sheet)

This International Search Report has not been established in respect of certain claims under Article 17(2)(a) for the following reasons:

1. ☒ Claims Nos.: 1-26; 36-41
because they relate to subject matter not required to be searched by this Authority, namely:
Rule 39.1(iv) PCT - Method for treatment of the human or animal body by therapy
2. ☐ Claims Nos.:
because they relate to parts of the International Application that do not comply with the prescribed requirements to such an extent that no meaningful International Search can be carried out, specifically:
3. ☐ Claims Nos.:
because they are dependent claims and are not drafted in accordance with the second and third sentences of Rule 6.4(a).

B x II Observations where unity of invention is lacking (Continuation of item 2 of first sheet)

This International Searching Authority found multiple inventions in this international application, as follows:

see additional sheet

1. ☒ As all required additional search fees were timely paid by the applicant, this International Search Report covers all searchable claims.
2. ☐ As all searchable claims could be searched without effort justifying an additional fee, this Authority did not invite payment of any additional fee.
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4. ☐ No required additional search fees were timely paid by the applicant. Consequently, this International Search Report is restricted to the invention first mentioned in the claims; it is covered by claims Nos.:

Remark on Protest

- ☐ The additional search fees were accompanied by the applicant's protest.
- ☒ No protest accompanied the payment of additional search fees.

FURTHER INFORMATION CONTINUED FROM PCT/ISA/ 210

This International Searching Authority found multiple (groups of) inventions in this international application, as follows:

1. Claims: 27-33

A heart contracting apparatus comprising a controller for first and second magnets on first and second sides of a heart chamber.

2. Claims: 34-35

A heart contracting apparatus comprising a band placed around the heart having a gap bridged by an electromagnetic actuator reducing said gap upon actuation.

INTERNATIONAL SEARCH REPORT

Information on patent family members

In ational Application No

PCT/US 99/08591

Patent document cited in search report		Publication date	Patent family member(s)	Publication date
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